SNC-134.US (5008-134-10)

Schedule A

to the Response of June 23, 2005, Serial No. 10/783,032

Amending the Claims

1. - 13. (Cancelled)

14. A jacketed projectile having front and rear ends separated by the length of the projectile and comprising:

a) an engravable jacket, and

b) a central core, the central core having a midsection portion which is not in continuous contact with the jacket over at least a portion of the midsection portion to allow engraving to occur on the jacket without full support from the core,

wherein the midsection portion is tapered, tapering towards the front end of the projectile to allow for progressive engraving of the jacket when the projectile is fired through a rifled barrel.

15. A jacketed projectile as in claim 14 comprising a fully encircling gap between the jacket and the core along at least a portion of the length of the midsection portion of the core.

16. A projectile as in claim 15 wherein the encircling gap is in the form of a tapered gap present between the jacket and the midsection portion along at least a portion of the length of the midsection portion.

17. A projectile as in claim 15 wherein the encircling gap is in the form of a fully encircling tapered gap present between the jacket and the full length of the midsection portion.

18. A projectile as in any one of the preceding claims wherein the midsection portion is frusto-conical in shape.

19. A projectile according to claim 18 wherein the half-conical angle of the frusto-conical

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portion of the core is between 0.7° and 1.0°.

20. A projectile according to claim 18 wherein the half-conical angle of the frusto-conical portion of the core is between 0.85° and 0.95°.

21. A projectile according to any one of the preceding claims comprising a short cylindrical portion of the core having an outer surface, the cylindrical portion extending rearwardly from the midsection of the core, wherein the jacket and outer surface of the cylindrical portion are in generally continuous contact with each other for the length of the cylindrical portion.

22. A projectile according to claim 21 wherein the cylindrical portion of the core is less than 30% of the length of the midsection portion.

23. A projectile as in any one of claims 15, 16 or 17 wherein the gap is occupied by a compressible medium.

24. A projectile as in claim 23 wherein the compressible medium is air.

25. A projectile as in any one of the preceding claims wherein the central core is principally composed of a material selected from the group consisting of carbon steel, tungsten, tungsten carbide, tungsten alloys, tungsten-nylon compounds, tungsten-tin compounds and mixtures thereof.

26. A projectile as in claim 25 wherein the central core has a hardness and the hardness of the central core is at least 45 on the Rockwell C hardness scale.

27. A projectile as in claim 14 wherein the core comprises a forward portion mounted ahead of the midsection, said forward portion having an ogival shape over at least a portion of its surface and wherein the junction between

28. A projectile as in claim 27 comprising an inwardly tapering end portion of the core positioned rearwardly of the cylindrical portion.

29. A projectile as in claim 28 wherein the rearwardly tapering end portion of the core has a half-conical angle of about 7 degrees.

30. A projectile as in any one of the preceding claims wherein the jacket material comprises gilding metal.

31. A projectile in accordance with claim 30 wherein the gilding metal jacket comprises approximately 90% copper and 10% zinc.

32 A projectile according to claim 31 wherein the gilding metal jacket is thicker than that normally used on conventional ball projectiles of similar calibre.

33. A projectile according to any one of the preceding claims in combination with a casing to form a cartridge, the casing being dimensioned to fit into a standard firearm wherein the overall length of the projectile is greater than that of a conventional ball projectile of similar caliber and wherein the projectile, when fitted into its casing, provides a cartridge with a length suited to fit into a standard firearm having a casing of the same diameter.

34. A projectile and casing combination in the form of a cartridge as in claim 33 wherein said cartridge is free of toxic components.

35. A projectile and casing combination in the form of a cartridge as in claim 33 wherein said cartridge is lead-free.

36. A jacketed projectile as in any one of the preceding claims wherein the central core is a solid, one-piece core.

SNC-134.US (5008-134-10)

Schedule B
to the Response of June 23, 2005, Serial No. 10/783,032
Amending the Disclosure

[002] Historically, small calibre projectiles have been made from lead alloys **- Fig. 1 -** or contained lead cores. Lead is an easy metal to form due to its' ease of malleability (very low Young's modulus) and projectile cores of this material readily deform under the high engraving stresses associated with a projectile being fired from a rifled gun barrel. Both of these material properties provide advantages for projectile design and permit good accuracy performance and low gun barrel wear.

[003] However, in order to mitigate the barrel fouling associated with 1-piece, all-lead projectiles, copper-zinc alloy, (also known as gilding metal) jackets were introduced **- Fig. 2 -**.. These projectile jackets are thin enough in profile and ductile enough to deform adequately under the engraving stresses and transfer the spin from the rifling and still retain projectile integrity when the projectile leaves the muzzle of the gun. These 2-piece projectiles are still in production today, mainly for hunting and some military applications.

[004] Further advances to projectile design have resulted in copper jacket projectiles with a short, conical hardened steel penetrator in the tip of the projectile and a cylindrical lead core at the aft of the projectile **- Fig. 3 -**. Antimony is often added to the core for increased mechanical strength. The jacket allows the integration of the two (penetrator and core elements) to reach the target together and provide as well the desired interior ballistic performance. This style of three-piece projectile is commonly referred to as "ball" ammunition. This design has improved terminal ballistic effects over all-lead core projectiles and allows increased penetration of hard targets due to the addition of the very hard penetrator while still permitting good accuracy and acceptable barrel wear due to the lead/antimony alloy core.

[0014] Many different materials and combinations of materials have been considered as replacements for the lead core in the manufacture of non-toxic projectiles. See U.S. Patent 6,085,661 in which copper is used as a replacement for lead **- Fig. 4 -**.

[0028] The contact surface of the projectile is called the "driving band". This is the area of the projectile that is in direct contact with the rifling of the weapon and undergoes plastic deformation when fired through a gun barrel. In conventional ball projectiles, the lead core

under the copper jacket is in the position of the driving band. The soft copper jacket and malleable lead core are ideal materials for a driving band since they are readily plastically deformed and lengthen longitudinally under axial compression in accordance with Poisson's ratio for these metals **- Fig. 6 -**.

[0039] Another well-known disadvantage with conventional ball ammunition is its tendency to fragment into many pieces upon impact with a ballistic gelatine target **- Fig. 9 -**. Ballistic gelatine is a material commonly used as a simulation for human tissue to establish terminal ballistic performance. The requirement for a non-fragmenting projectile stems from Hague convention IV of 1907, which forbade projectiles or materials calculated to cause unnecessary suffering to the opposing soldiers on the battlefield. An example of a prohibited projectile is the now infamous Dum-Dum projectile which was judged to cause excessive suffering **- Fig. 8 -**.

[0054] Upon further examination and analysis, it is learned that a longer, one-piece all-steel core, copper jacketed projectile can be made to nearly match the weight of the conventional projectile if it is extended in length to approximately the same length as a conventional tracer projectile **- Fig. 5 -**. This means that such a new projectile design could still be produced and assembled on existing projectile manufacturing equipment and assembled into complete cartridges using existing cartridge assembly equipment without requiring significant or expensive tooling modifications. Thus, the length over diameter ratio, or L/D must be greater for a steel core projectile than for a conventional lead core ball projectile in order to retain the same projectile mass.

[0064] Figure 9 shows an image of **a** broken projectile~~therein, (refer to DREV report)~~.

[0065] Figure 10 shows **a side-view of the core design of the projectile of the invention**~~an image of the IP core design~~.

[0066] Figure 11 shows **a cross-sectional side view of the projectile of the invention**~~an image of the IP projectile.~~

[0067] (deleted)

[0068] Figure 12 is a ~~partial~~side ~~section~~view of an all-steel core projectile **according to the invention** with the various ~~portions~~**characteristics** of the core **identified**~~in evidence~~.

[0069] (deleted)

[0070] (deleted)

[0071] (deleted)

[0075] One embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings. ~~[, of which:]~~

[0076] Referring to the **Figures 10, 11 and 12 of the** drawings, an all-steel core projectile is made of a copper alloy or gilding metal jacket 11 and an all-steel core 12.

[0077] A frusto-conical **mid-section** portion 14 of the all-steel core~~[, 14]~~ 12 extends rearwardly from the ogival front end 15, the frusto-conical portion 14 having a **preferred** small **half-conical** angle **or side taper** of approximately 0.85°, whereby the junction of the ogival front end 15 and the frusto-conical portion 14 provides a relatively smooth blended junction.

[0078] There is a gap 17 between the projectile jacket 11~~[,]~~ and the frusto-conical portion of the core 14, such that the two are not in continuous contact. **This is shown in Figure 11.**

[0079] A short cylindrical section of the core~~[,]~~ 16 extends rearwardly from the frusto-conical portion 14 of the core 12 and serves as the principle driving band. **This cylindrical section 16 is preferably about one-third of the length of the mid-section 14, as indicated in Figure 12.**

[0080] Rearwardly of the short cylindrical section 16~~[,]~~ is a short rearwardly tapering end section~~[,]~~ 13 with a **preferred half** conical angle of approximately ~~[83°]~~ 7°.

[0081] It is therefore the object of the invention to provide a jacketed, non-toxic projectile which:

1. contains no lead or heavy metals;
2. has a one-piece steel core;
3. the core is made of a hardened (approx. 0.4% carbon) steel for improved penetration performance in hard targets;
4. meets industrial and military specification requirements for gun barrel wear;
5. chamber pressure;
6. accuracy;
7. projectile integrity;
8. stability in flight; and
9. will not fragment upon impact in ballistic gelatine, even at very short ranges;

10. has a thicker copper alloy jacket than standard ball rounds.

[0082] According to the invention, the forward portion of the all-steel core 12 has an ogival shaped front end 15 followed by frusto-conical portion 14 with a small conical angle, whereby the exterior surface of the frusto-conical portion 14 of the core 12 is not in continuous contact with the interior surface of the projectile jacket 11. The gap 17 between the jacket 11 and the core 12 is filled with air. The frusto-conical section 14 merges into [a]**the** short cylindrical section 16, followed by a final tapered section 13 that extends backwards from the rear end of the short cylindrical section 16.

[0083] The ogival section 15 of the projectile is essential in facilitating projectile feeding from weapon magazines and/or belts. An ogive presents a smooth surface with no angles to get caught on weapon components during feeding to the chamber.

[0084] The projectile core 12 is preferably made of hardened AISI 1038 steel, or other hard material with a Rockwell hardness of 45 or greater on the "C" scale to ensure improved penetration of hard targets.

[0085] The jacket 11 of the projectile is preferably made of a ductile copper/zinc alloy or gilding metal containing approximately 90% copper and 10% zinc. The thickness of the jacket 11 is also helpful in meeting the barrel wear criterion. The jacket thickness of the preferred embodiment is slightly thicker than conventional ball projectile jackets. A thicker copper alloy jacket requires no additional special coatings or other special treatment to reduce friction and acts as a friction-reducing medium between the hard steel core 12 and the gun barrel.

[0086] The projectile is assembled such that the jacket 11 is in direct contact with the one-piece core 12 on the ogival front end 15, the short cylindrical section 16 and the rearwardly tapering end portion 13. There is a small air gap 17 between the projectile jacket 11 and the frusto-conical portion 14 of the core.

[0087] The gap 17 is generated due to the slight angle of the frusto-conical portion of the core. The angle of this section is **most** preferably 0.85°, but may range **between 0.06° to 1.13°, more preferably** between 0.7° and 1.0°. This gap 17 allows the **overlying** copper jacket 11 material to flow plastically during engraving and compensate for the unyielding hard steel core 12 underneath. The deformation of the jacket 11 must be sufficient to maintain acceptable chamber

pressure values, but not so great as to hinder the transfer of projectile spin and thus stability. This narrow range of angle is very important to ensuring the accuracy of the projectile in flight, but is not the only factor involved.

[0088] The value of the angle of the frusto-conical portion 14 of the core 12 is critical since too large an angle will result in an undersized ogival front end 15 and the projectile will not be properly supported in the barrel. This will lead to an increase in projectile yaw and reduced accuracy on the target.

[0089] If the angle of the frusto-conical portion 14 of the core 12 is too small, the gap 17 will be too small, the cylindrical parallel portion will be too long and increase projectile engraving forces. The length of the cylindrical parallel portion 16 must be much less than the length of the frusto-conical portion 14.

[0090] The ratio of the length of the short cylindrical section 16 (driving band) of the core 12 to the longer frusto-conical section is very important for maintaining stability of the projectile in flight. This ratio should be preferably less than **0.33**{~~0.3~~}, but may range between 0.3 and 0.1, with best results obtained at a ratio of 0.2. If the cylindrical parallel portion 16 is too long, excessive chamber pressure and barrel wear will result. If this portion 16 is too short, the projectile will slip in the gun barrel rifling and diminish in stability in flight, thus affecting accuracy.

[0091] The section of jacketed projectile that acts as the driving band (over the cylindrical parallel portion 16 of the core 12) is in continuous contact with the rifling, while the frusto-conical section **14 of the jacket 11** is only partially and progressively in **supported** contact with the rifling. This tapered gap 17 between the jacket 11 and the frusto-conical portion 14 of the core 16 is key to the invention, since it allows the projectile to have acceptable internal and external ballistic performance characteristics, with greatly enhanced terminal ballistic properties due to the hard steel core. The taper allows for {~~gradual~~} **gradually supported** engraving **to occur in the jacket 11** to ensure acceptable stresses while maintaining good precision on the target. Other designs were tried, whereby the gap 17 was cylindrical or other non-conical shapes and the target accuracy {~~always~~} suffered {~~greatly~~}.

[0092] As the jacketed projectile starts advancing down the barrel rifling from its starting position in the forcing cone of the rifling, it gradually and progressively engraves in the lands and

grooves of the rifling. The exact initiation point of **partial** engraving occurs somewhere along the length of the frusto-conical section **14** of the core **12** and is fully complete when it is in full contact with the short cylindrical section **16**. This feature is very important since the various small calibre weapon platforms have different land and groove diameters, and can be found in various states of wear and in this way these differences can be accommodated.

[0093] If the gap **17** were to be filled with another material, it would have to be inexpensive, easy to manufacture, very easily compressible and not have any deleterious affect on the projectile jacket **17** during the compressive action of engraving. Otherwise it could potentially cause the jacket **11** to rupture when it is being deformed through engraving. This could be a second, less cost-effective variant however.

[0094] Several tests were made during the development of this new projectile; involving various combinations of angles and lengths of the two main core portions **14, 16**. High chamber pressures (380 Mpa) were measured when the length of the cylindrical section **16** was too long. This is over NATO specification limits and potentially dangerous. The final configuration resulted in pressures around 330 Mpa.

[0095] Several tests were also made to establish the optimal angle of the frusto-conical section. The first test resulted in a barrel that was worn beyond acceptable limits after only 2,000 rounds fired in approximately 90 minutes, as per NATO specifications. On the second try, after several months of design effort the angle was slightly increased and the length of the cylindrical section **16** was reduced. This time the barrel only became excessively worn after 4,000 rounds fired.

[0096] On the third and successful attempt, the diameter of the steel core driving band **16** and the length of the cylindrical section **16** were slightly reduced and the projectile passed the NATO barrel wear performance requirements, even after 5,000 rounds were fired. When the diameter of the driving band portion **16** of the steel core **12** was further reduced, accuracy on target was greatly diminished.

[0097] These tests were performed over a couple of years.

[0098] Several accuracy tests were also performed over this period to evaluate the best angle and length of the two key core sections **14, 16**. The taper angle on the core **12** is essential to meeting accuracy requirements, since the projectile is progressively supported in the barrel as it advances down the rifling.

[0099] The radius at the junction of the rear face of the rearwardly tapering section (the boat tail section) must be sufficiently large**, e.g. 0.025 inches,** to allow adequate mating of the copper alloy jacket **11** over the base of the core. If the radius is too small, the jacket material does not adhere, or close properly. This may result in high pressure propellant gasses infiltrating between the two components (core **12** and jacket **11**) and cause projectile stripping the moment the projectile leaves the barrel and is no longer supported by the rifling of the gun barrel.